Current Applications of Probabilistic Safety Assessment for Nuclear Power Plants

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We are Living in an Interesting Time

- In Support of Nuclear Power
  - PSA Standard
    - Level 1 PSA, shutdown and external events
    - Fire PSA
    - Level 2 PSA
    - Level 3 PSA
  - Regulatory Measures
- Security Applications
- Use in Regulatory Environment
- Software/Methodology Advancements/Issues

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Commercial Nuclear Power

- Regulatory and Economic Drivers
  - PSA has become key part of communication between utilities and regulators
  - There is movement on “risk-informing” regulations
  - Utilities are expanding internal use to support decision making, supplement training, etc.

Regulatory Guide 1.174

- Provides guidance on acceptability of changes to plant based on risk
- Limits increase in core damage frequency and frequency of large early releases
- Addresses completeness of PSA including external events and sources of uncertainty

PSA Quality

- USNRC is encouraging increased quality by calling for “completeness” by 2008
  - All initiating events
  - All modes of operation
- Joint regulatory/utility development of standards
  - Level 1, external events, low power and shutdown, fire, Level 2 and Level 3

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Mitigating System Performance Index

- MSPI combines unavailability and unreliability data with plant-specific risk importance measures to indicate the performance of key safety systems
- System performance requirements based on PRA system success criteria vs. design basis requirements
- Performance is measured relative to an industry baseline
- Systems
  - EAC, HPI, RHR, AFW/RCIC, Cooling Water (CCW plus SW)
- Monitor the most risk significant components
- Replaces reactor oversight process system cornerstone measures

License Extension and Power Uprate

- Application to extend license for an additional 20 years
  - PSA to support identification of cost effective “severe accident mitigation alternatives” using ROI and Level 3 results
- Power uprate: few percent for PWRs; up to 20% in BWRs
  - Need to rebaseline PSA

Risk-Informed Asset Management

- Developed jointly with EPRI and South Texas
- Integrates risk and economic model into utility business model
- Multi-attribute decision support including ROI

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Evolving Techniques leading to a New Generation of Risk Workstations

- Binary Decision Diagrams
  - Old mathematic formulation finding new applications
  - Eliminates need to determine cut sets
  - Extremely fast, can support real-time reevaluation of model
  - Will eventually eliminate distinction between large event tree and large fault tree methods
- Dynamic Modeling
- Declarative Techniques

Barriers

- Need to move forward from simplistic surrogate risk measures like core damage frequency and frequency of large early release
- Difficulties in risk informing certain regulations
  - Coincident large loss of coolant accident and loss of offsite power
- Support for methods development

Backup

Capability Categories Defined in Standard

CRITERIA	CAPABILITY CATEGORY I	CAPABILITY CATEGORY II	CAPABILITY CATEGORY III
1. Scope and level of detail: The degree to which resolution and specificity are incorporated such that the technical issues are addressed.	Resolution and specificity sufficient to identify the relative importance of the contributors at the system or train level including associated human actions.	Resolution and specificity sufficient to identify the relative importance of the contributors at the SSC level including associated human actions, as necessary [see Note (1)].	Resolution and specificity sufficient to identify the relative importance of the contributors at the component level including associated human actions, as necessary [see Note (1)].
2. Plant-specificity: The degree to which plant-specific information is incorporated such that the as-built and as-operated plant is addressed.	Use of generic data/models acceptable except for the need to account for the unique design and operational features of the plant.	Use of plant-specific data/models to capture to the extent practical all significant features represented in the scope of the PRA model.	Use of plant-specific data/models to capture to the extent practical all significant features represented in the scope of the PRA model.
3. Realism: The degree to which realism is incorporated such that the expected response of the plant is addressed.	Departures from realism will have moderate impact on the conclusions and risk insights as supported by good practices [see Note (2)].	Departures from realism will have small impact on the conclusions and risk insights as supported by good practices [see Note (2)].	Departures from realism will have negligible impact on the conclusions and risk insights as supported by good practices [see Note (2)].

NOTES:

(1) The definition for Capability Category II is not meant to imply that the resolution and specificity is to a level to identify every SSC and human action; only those necessary for the specific SR. Similarly for Capability Category III, it is not meant to imply that the resolution and specificity is to a level to identify every sub-component for every component.

(2) Differentiation from moderate (conservative or acknowledged, potential non-conservative), to small, to negligible is determined by the extent to which the impact on the conclusions and risk insights could affect a decision under consideration. This differentiation recognizes that the PRA would generally not be the sole input to a decision. A moderate impact implies that the impact (of the departure from realism) is of sufficient size that it is likely that a decision could be affected; a small impact implies that it is unlikely that a decision could be affected, and a negligible impact implies that a decision would not be affected.

PRA Elements

- Initiating Events Analysis (IE)
- Accident Sequence Analysis (AS)
- Success Criteria (SC)
- Systems Analysis (SY)
- Human Reliability Analysis (HR)
- Data Analysis (DA)
- Internal Flooding (IF)
- Quantification (QU)
- LERF Analysis (LE)

Objective and High Level Requirements

- Provided for each PRA element
- Minimum requirements for meeting this Standard in general terms
- Example of IE objective: To identify and quantify events that could lead to core damage
- Example of IE HLR; The IE shall provide a reasonably complete identification of initiating events

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Supporting Requirements

- Minimum requirements for each PRA element necessary to meet that capability category
- Example of SRs:
  - Use a structures, systematic process for identifying initiating events (for I, II, III).
  - Perform a systematic evaluation for each system to assess the possibility of an initiating event occurring due to a failure of the system (for II, III)

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Status of PRA Standards

- Industry has been using NEI-002 peer review process
- Industry not willing to use Standard until USNRC clarifies its acceptance of NEI-002 and ASME Standard
- Standard has been used during peer review to help in grading PRAs
- USNRC has developed Draft Reg Guide 1122 to provide USNRC's position on the PRA Standards

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A Few Words on NFPA 805

- Performance based standard for fire protection for nuclear power plants
- Published in 2001
- An alternative for meeting the fire protection requirements of 10 CFR 50.48
- Licensees could focus their resources on most risk-significant fire protection equipment and activities for each plant
- USNRC is in the process of rulemaking for licensee to adopt NFPA 805
- NEI is in the process of developing a guidance document for implementing the program

NFPA 805 Process

- Confirm Fundamental Fire Protection Program
- Identify Fire Areas and Fire Hazards
- Identify Goals and Performance Criteria
- Identify SSC's in Each Fire Area
- Select Deterministic or Performance Based Paths
- Perform Plant Change Evaluations (Fire PSA)
- Confirm Documentation and Configuration Control
- Establish Monitoring Program

USNRC Research Activities in Fire

- USNRC Fire Research Workshop on Communicating Research Results to End Users on August 2001
- Topics Discussed:
  - Overview of FRA methods and related issues
  - Fire PRA application insights
  - Methods of circuit analysis (“Hot Short” issues)
  - Cable failure modes and effects experimentation and data
  - Fire model benchmarking
  - Frequency of challenging fires (“Severity Factors”)
  - Detection and suppression data and analysis
  - Fire risk methods insights from nuclear power plants fire events
- Results showed inadequacies in present methods without showing how they can be improved

Security

- PSA has played a significant role in addressing security and vulnerability issues associated with directed human threats
- Examples:
  - Detailed structural analyses given aircraft crash, explosive, or other threat
  - Response to assumed set of scenarios
  - Target prioritization

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Understanding the Adversary

- The 1979 NUREG 0459 provides a framework to understand adversaries
- Several groups are identified ranging from sophisticated terrorists to common criminals
- Groups differ by goal and means to reach those goals

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Scenario Quantification

- Techniques are available to quantify scenarios
  - Large uncertainties
  - Incorporate information from, for example, surveillance detection programs

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Barriers

- Some methodology development still needed
  - For example, how to address risk management when scenarios are linked in “intelligent” ways
- Resistance to change

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